

THE ISO-DEFORMATION CURVES OF IMAGES AND THE CRITERION FOR DELIMITATION OF THE USABLE AREAS IN CINE-AUDITORIUMS

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It is known that the Cinema is possible mainly because of the deficiencies of our eye-sight as an optical instrument. In the first place because of the residual impression of the images which allow the illusion of continuity in the sequence of the pictures, and also because of the extraordinary tolerance we have for the distortion of the projected images. If our sight tolerated only the perfect image, no obliquity would be permissible and the movie theatre would be restricted to one single seat.

The delimitations of the useful areas adopted until the present time have been based simply upon straight segments which form a certain angle with the projection screen and starting now from the extremities of the screen, now from the center. The same criterion is adopted both horizontally and vertically. Such method is good only for part of the areas. Being aleatory, and not founded upon real principles, it disconcerts the project-engineer, inducing him to arbitrary solutions.

Faced with the projects of various cinematographs, and searching for more perfect solutions, we were induced to ask the following questions:

1. What are the origins of the distortions of the projected images on the screen?
2. How does the viewer react to the distortions?
3. How to draw an outline in the auditorium where the apparent distortions are equal?
4. What are the influences of the curvature and dimensions of the screen on the distortions of the images?

The distortions of the images can evidently be originated by the obliquities or abnormalities of the projection equipment itself; in this case they are

called real. We are not going to admit, at the beginning, the real distortions but only the apparent. These are caused by obliquity of viewing.

We divide the apparent distortion in two categories. One, when the image is motionless and which depends exclusively on the viewing angle. When the projected image is a circle, it will be viewed as an ellipse, at any position outside the perpendicular visual. The other type of distortion depends on the movement of the image.

If a circle moves on the screen with no change in diameter, at the same rate, from one extremity to the other, the apparent image also changes sizes as the distance varies. In this way, we have the impression that the object gets farther away or gets closer when the parallax of viewing is diminished or augmented, respectively. Likewise, images in symmetrical extreme positions will appear to be farther back in depth one from the other.

Obviously, we cannot expect people to react in the same way to the same phenomenon of distortion. Several personal factors have an influence in each case:

1. visual acuity
2. visual accomodation
3. habit
4. aesthetic and technical requirements
5. interest in the motive
6. viewing time
7. speed of the visuals.

In addition to these, there are also the impersonal influences:

1. shape of the images
2. clarity of the images
3. center of attention of the picture
4. projection time of the image.

As we can see, physical and psychological factors have an influence in the re-

tion of each viewer. In any case, we can admit for every viewer there will be an area of viewing in which the distortions are not noticeable; another area in which the distortions are noticeable but tolerated, and finally, a third one in which the distortions will not be tolerated. Since it varies from person to person, and possibly also from occasion to occasion, we must find medium values to represent the average viewer. Before doing that though, we should define the group of points that represent the places in the auditorium where the viewers view the images under apparent distortion. We could call these points line of the "iso-deformation".

This definition is the main goal of our present work.

As we have explained previously, we must divide the apparent distortions in two categories. One, the distortion due to the viewing of the still images; the other, the distortion of the images moving along the screen, i.e., the distortion of the images in motion.

APPARENT DISTORTIONS OF THE STILL IMAGES

Let us suppose that the image of a circle of diameter c (fig.1) is viewed perpendicularly from a distance d by a viewer M_1 . If we move M_1 to M_2 , with d , invariable around O at an angle γ , the image of the circle A will evidently become the ellipse B . The main axis of the ellipse will remain equal to the radius of the circle, but the parallax W of the circle will become the parallax W' of the minor axis of the ellipse.

The ratio $\frac{W}{W'} = n$ is the index of distortion of the image viewed at an angle γ .

And for a c sufficiently small in relation to d the equation is true.

$$\frac{W}{W'} = \frac{1}{\cos \gamma} = n$$

For a constant n this equation represents a cone. The intersection of this cone with the viewing surface of the room, gives the curve whose points M define an equal distortion. The images at the top vertices of the screen are the

ones that show the maximum distortion.

As a rule, we should draw the intersection of the cone (with an axis perpendicular to the screen at the top corners) with the viewing surface of the auditorium (which is generally close to a logarithmic of revolution). But since the incurring error is negligible, we may consider the screen as vertical and the viewing surface flat and horizontal. Thus the intersection of the cone with the plane gives a hyperbola which makes the outline much easier to be drawn (fig.2).

The enveloping line of the hyperbola, which follows the image from one extremity of the screen to the other, is the limiting line of viewing, for a certain value of n . Tracing the outlines for a flat (fig.3) and for a cylindric screen (fig.4), we find that the curved one offers a more useful viewing area to the viewers close to the screen than the flat one.

DISTORTION OF THE IMAGES IN MOTION

Let us suppose now that the image of a circle moves on the screen, at the same altitude, from an extremity A to another B, with a constant diameter c . A viewer at M will view the image according to a horizontal parallax varying from W to W' . The ratio $\frac{W}{W'} = m$ is the index of distortion of the image viewed by M. In fig.5 which represents the horizontal section of a cylindric screen, the following elements can be identified:

- AB projection screen
- P center of curvature
- s radius of curvature
- b base of screen
- M viewer
- c diameter of the circle-image

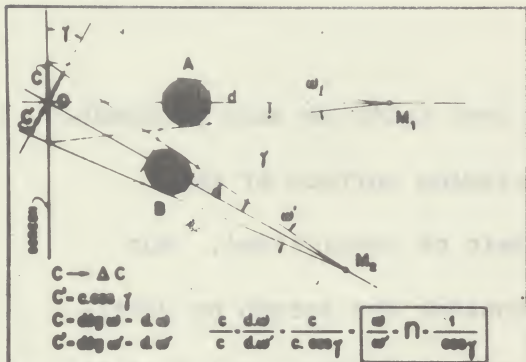


FIG. 1

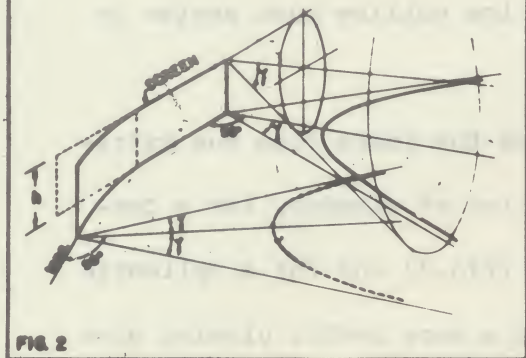


FIG. 2

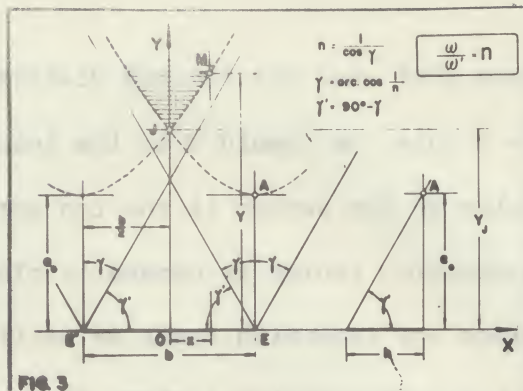


FIG. 3

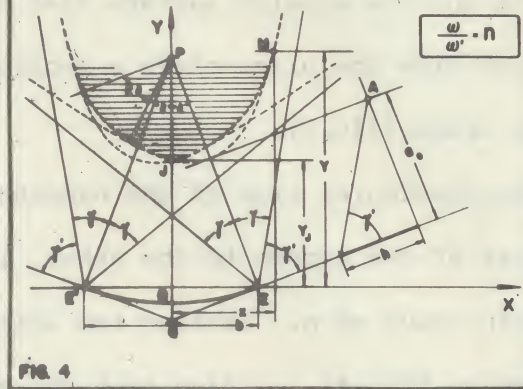


FIG. 4

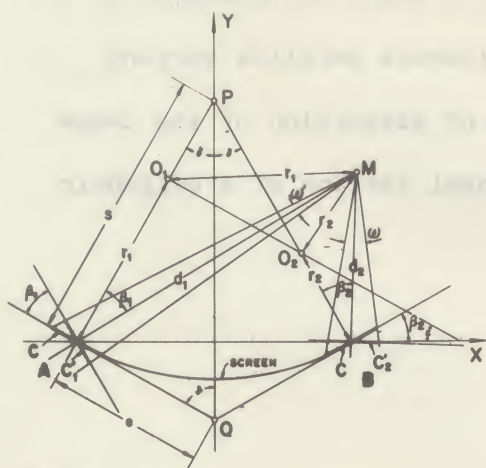


FIG. 5

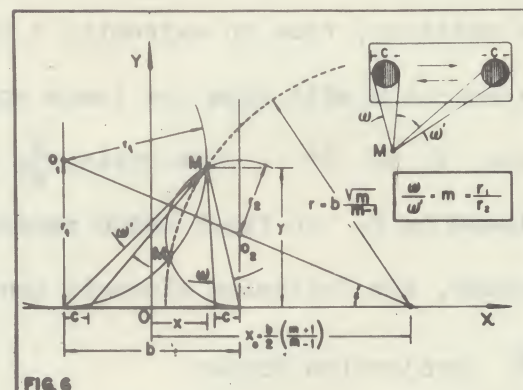


FIG. 6

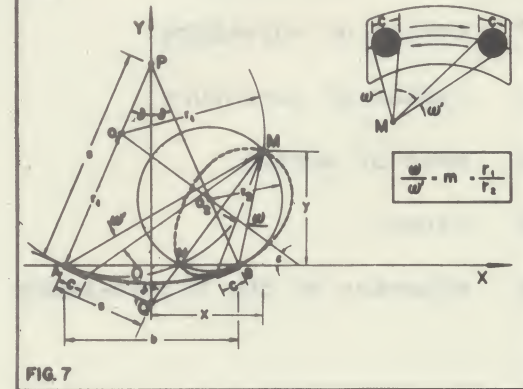


FIG. 7

W parallax of c at A

W' parallax of c at B

r_1 radius of the circle tangent to the screen at A with center O_1 in $\overline{AP}$

r_2 radius of the circle tangent at B with center in O

d distance from the viewer to the image.

For a c sufficiently small in relation to d , we have:

$$c'_1 = c \cos \beta_1 = d'_1 W' = 2r_1 \cos \beta_1 W'$$

$$c'_2 = c \cos \beta_2 = d_2 W = 2r_2 \cos \beta_2 W$$

$$c = 2r_1 W'$$

$$c = 2r_2 W$$

$$\boxed{\frac{W}{W'} = \frac{r_1}{r_2} = m}$$

The index of distortion is then $m = \frac{W}{W'}$ and is equal to the ratio between the ratio r_1 and r_2 of the circles which are tangent at A and B and whose centers O_1 and O_2 move along the perpendiculars to the extremities of the screen.

ZONING OF THE AUDITORIUM

We have admitted previously that for each viewer, there will be a certain number of areas in which the apparent distortions of the images exist but are not noticed (zone I). Next, there will be another area where the distortions are noticed but tolerated (zone II). Beyond that, the distortions will no longer be tolerated and the viewer will refuse to use the seats placed there (zone III).

We have the elements for the outline of such areas. The difficult part is to define the indices of distortion n and m in function of the many factors, personal and impersonal, and which vary from viewer to viewers.

For every geographic region and for each particular case - type of projection, if for commercial or educational screening, etc. - the indices n and m could be fixed, for the average viewer, through statistic studies.

In the projects we have made of commercial projectors, with a large screen (1:2.55) calling zone I "good", zone II "fair" and zone III "poor", we obtain best results adopting the following values:

Zone I	good	$n \leq 1,1$	$m \leq 1,4$
Zone II	fair	$1,1 < n < 1,4$	$1,4 < m < 2,0$
Zone III	poor	$n \geq 1,4$	$m \geq 2,0$

The intersection of the circles is the curve of the iso-distortions. It presents several branches. The branch that interests us, fig.7, though, is the one within the possible viewing field of M. It is an oval, whose existence is defined for

$$\text{e. to } \frac{\psi + \epsilon}{2} \leq r_1 \leq s \quad \text{where } \epsilon = \arcsin \frac{m-1}{m+1} \sin \psi \text{ and } 1 \leq m \leq \infty.$$

We have not attempted the analytical outline because it is too complex. Giving successive values to r_1 and r_2 , the graphic outline through points is very simple and rapid. On the flat screen, fig.6, the oval becomes a circle of radius $r = b \frac{\sqrt{m}}{m-1}$ whose center has as abscissa $x_0 = \frac{b}{2} \cdot \frac{m+1}{m-1}$.

Comparing the curves of M (for the same value of m) we notice that for the curved screen there is a greater usefulness of the area of the room than for the flat one.

The delimitation of the areas of movie-theaters by means of definite indices of distortion of the images, presents the following advantages:

1. Economy due to a rational utilization of the space available.
2. Better convenience to viewers.
3. Reliability in the making of new projects and re-study of theaters already existent.
4. And last - the one we think the most important - the possibility of technical standardization and classification of the theaters already existent.

TECHNICAL STANDARDS

In what concerns the apparent aberrations of the images, the following should be done:

1. To fix, for each type of exhibition, the values of m and n which correspond to the limits of zone I and zone II.
2. To fix also a maximum value of the percentage of zone II as related to zone I.

In this work we are taking into consideration exclusively the apparent distortion for the delimitation of the areas. The areas are open and a viewer could move farther away indefinitely, without any increase in the distortion of the images.

To define the depth of the room other factors such as the minimum total parallax, synchronism of image and sound - things which are not the concern of the present work - should also be taken into consideration, and good and tolerable areas should be delimited for them, independently.

APPLICATION

We shall now discuss the application of the concepts related to the indices of distortion introduced in this work, to the different types of screening most usually employed.

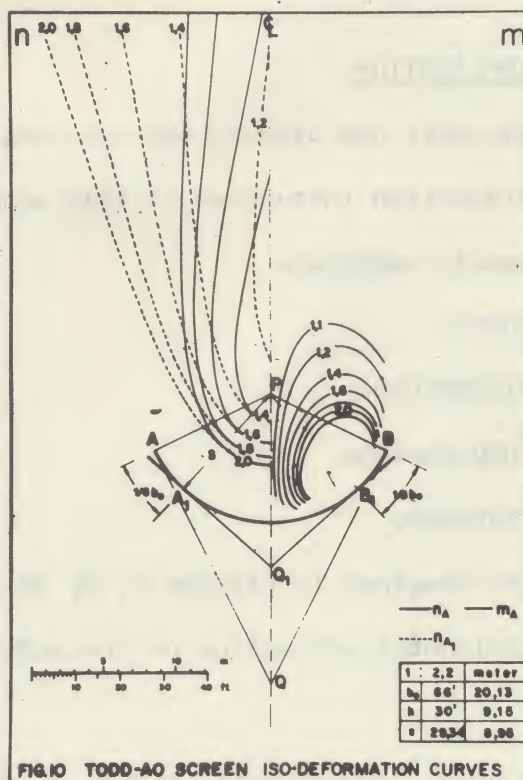
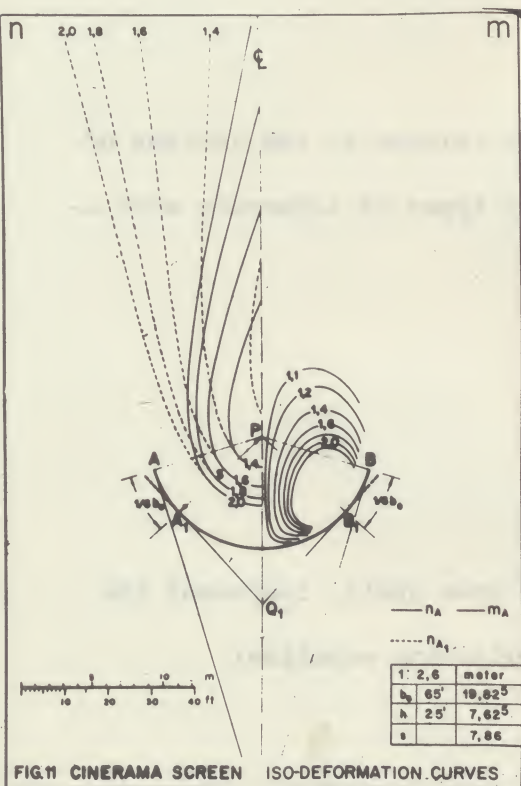
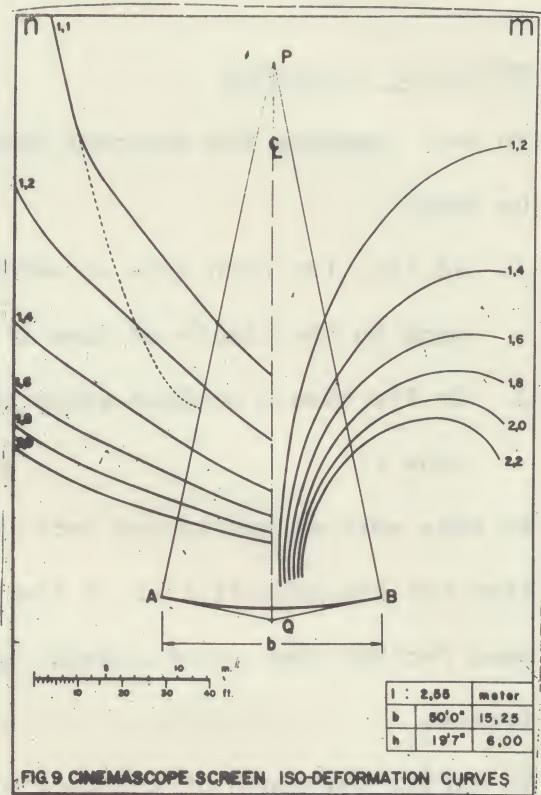
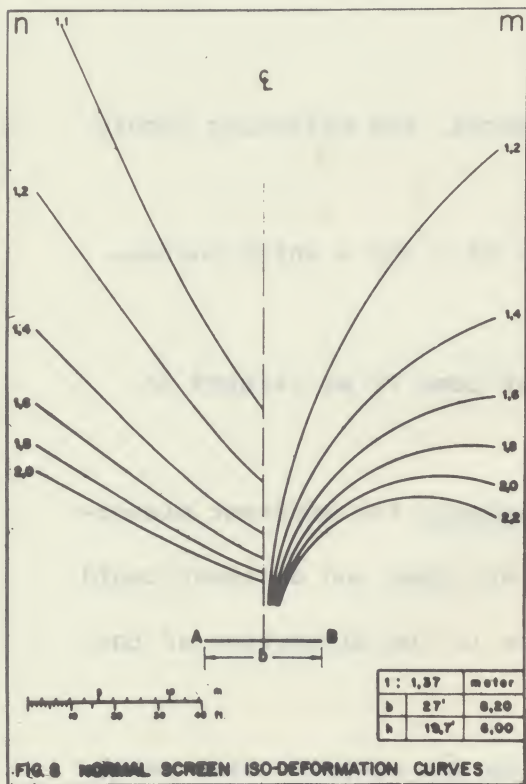
NORMAL

CINEMASCOPE

TODD-AO-70mm

CINERAMA.

The drawings in figures 8, 9, 10 and 11, all in the same scale, represent the horizontal projection of the auditorium, with the following notation:



- P center of curvature of the screen
- s radius of curvature of the screen
- b base of the screen (the cord in Cinemascope)
- b_0 developed base of the screen
- h height of the screen
- m indices of distortion of the moving images
- n indices of distortion of the still images

Due to symmetry, the curves of m and n were represented in a single drawing.

The curves of n were drawn for the surface of viewing as the plane containing the base of the screens. In this way, with negligible error, the drawings can be used, in the due proportions, for screens with different dimensions.

TRADITIONAL SCREEN

The flat screen in the regular proportions (1:1,37), fig.8, though with larger dimensions, is still very much used, not only by commercial exhibitors, but especially in schools and small auditoriums.

Since the visual field is small because of the proportions of the screen, the curves n and m were drawn in relation to the images on the top vertices.

The curves represent therefore the maximum apparent distortions.

CINEMASCOPE

Using a flat screen with the same height of the REGULAR, the CINEMASCOPE process (1:2,55 will obviously make areas I and II smaller.

For a cylindric screen though, as shown in fig. 9, the usefull areas surpass the ones for the FLATT REGULAR screen.

We adopt a radius of curvature s equal to the distance from the projector P to the screen with center in P.

- P center of curvature of the screen
- s radius of curvature of the screen
- b base of the screen (the cord in Cinemascope)
- b_o developed base of the screen
- h height of the screen
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We adopt a radius of curvature s equal to the distance from the projector P to the screen with center in P.

In this case too, the curves m and n for the images at the limit side and top positions are represented in fig.9.

TODD-AO and

CINERAMA

Fig.10 represents a cylindric TODD-AO screen with an angle of 128° , height h and base b_0 with a 1:2,2 proportion for projection of 70mm films.

Fig.11 represents the CINERAMA screen 1:2,6 for 3 projectors of 35mm, having a curvature of 146° .

These two screens should take special consideration, because of the feeling of "participation" that the viewers must have with the film being shown.

So that the effect of "presence" is not disturbed, the viewers should, theoretically, not be able to see the borders of the screen, or the borders should at least not fall within the periphery of the retina of the eye.

In this way, the limits for noticing the distortion of the images could be set beyond the borders of the screen, for the images outside the area of interest of the picture would also fall within the periphery of the retina. These considerations define too a greater utilization of the area of the auditorium.

We suggest that, figs. 10 and 11, the superior limit of the position of the images be fixed at $3/4$ of the total height of the screen and at $1/6$ of the side borders.

Going the other way around, as a natural consequence of the present study, it would be possible, the values of m and n being known, to study what type of screen would be more convenient for the wide screening of tridimensional effects by monocular means; a superficial analysis of figs. 10 and 11, shows how extremely limited the viewing area within the tolerable areas is.

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